VACUUM ARC VAPOR DEPOSITION APPARATUS AND VACUUM ARC VAPOR DEPOSITION METHOD

Background of the Invention

Field of the Invention

5   The present invention relates to a vacuum arc vapor deposition apparatus and a vacuum arc vapor deposition method used for forming a thin film of excellent lubricating property and hardness on such a substrate as an automobile part, machine

10   part, machine tool, and metal mold, which includes a magnetic coil for guiding a plasma produced by a vacuum arc evaporating source to the vicinity of the substrate. More particularly, the invention relates to a vacuum arc vapor deposition apparatus for preventing degradation of the uniformity of a thickness

15   distribution on a surface of the substrate, which is caused by the drift of the plasma in a magnetic field developed by the magnetic coil.

Description of the Related Art

20   A vacuum arc vapor deposition apparatus forms a film (thin film) on a substrate by using a vacuum arc evaporating source which vaporizes a cathode by vacuum arc discharge to produce a plasma containing a cathode material. The vacuum arc vapor deposition apparatus is advantageous in that a film forming

25   rate is high and highly productive.

The cathode material vaporized from the cathode of the vacuum arc evaporating source contains macro particles (called droplets) of several µm or larger in addition to micro particles suitable for film formation. The macro particles fly to and

5   attach onto the surface of the substrate, possibly damaging the adhesion property and smoothness (surface roughness) of the film.

To solve the above problems, the following two techniques are already proposed: 1) technique for transporting the plasma

10   to the substrate after the macro particles are removed from the plasma by the utilization of a deflection magnetic field (e.g., Japanese Patent Unexamined Publication No. 2001-3160), and 2) technique to make the macro particles fine by converging the plasma by the magnetic field to increase density of the

15   plasma (e.g., Japanese Patent Unexamined Publication No. 2000-34561).

Fig. 10 is a cross sectional view showing a vacuum arc vapor deposition apparatus which uses the technique 1) above. The vacuum arc vapor deposition apparatus includes a film forming

20   chamber (or vacuum chamber) 2 which is vacuum discharged by a vacuum discharging apparatus (not shown). A holder 8 for holding a substrate 6 on which a film is formed is located in the film forming chamber.

In this example, a gas 4, such as inactive gas or reaction

25   gas, is introduced from a gas source (not shown) into the film

forming chamber 2.

A bias voltage V_B of -50V to -500V, for example, is applied from a bias power source 10 to the holder 8 and the substrate 6.

5   The film forming chamber 2 is connected to a vacuum arc evaporating source 12 through a pipe 28 (deflection pipe) bent about 90° in this example.

The vacuum arc evaporating source 12 includes a cathode 14 mounted on an end plate 29 of the pipe 28 with an insulating

10   material 20 inserted therebetween. The cathode 14 is vaporized through vacuum arc discharge occurring between the cathode 14 and the pipe 28 serving also as an anode to produce a plasma 18 containing a cathode material 16. An anode electrode may be individually provided. Here, the "cathode material" means

15   material forming the cathode 14. An arc discharging voltage is applied from an arc power source 22 to between the cathode 14 and the pipe 28. The vacuum arc evaporating source 12 includes a known trigger mechanism, a water cooling mechanism and the like. Those mechanisms are not illustrated in the specification,

20   for simplicity.

A plurality of magnetic coils 24 are provided around an outer periphery of the pipe 28. The magnetic coils generate a magnetic field for deflecting the plasma 18 produced by the vacuum arc evaporating source 12, and guides (transports) the

25   plasma 18 to the vicinity of the substrate 6 in the film forming

chamber 2. Some of magnetic field lines 26 generated by the magnetic coils 24 are roughly illustrated in the figure, and as shown, those magnetic field lines extend substantially along an inner surface of the pipe 28. Those magnetic coils 24 are

5 connected in series, and fed with a coil current I_c for generating the magnetic field from a coil power source 30.

The plasma 18 produced by the vacuum arc evaporating source 12 is bent to substantially along the magnetic field lines 26 and transported to the substrate 6. The macro particles emitted

10 from the cathode 14 are electrically neutral or negatively charged in the plasma 18. A mass of the macro particle is considerably large. Accordingly, those particles go straight irrespective of the magnetic field, and hit the inner wall of the bent pipe 28 and hence fail to reach the substrate 6. As

15 a result, the plasma 18 little containing the macro particles is led to the vicinity of the substrate 6. Thus, it is prevented that the macro particles attach to the substrate 6. The apparatus which has the magnetic coils 24, pipe 28 and coil power source 30 (coil power source 40 in Fig. 1) as mentioned

20 above is also called a magnetic filter where attention is put on the macro-particle removing function.

Ions (i.e., ionized cathode material 16) in the plasma 18 thus transported to near the substrate 6 are attracted to the substrate 6 under the bias voltage V_B and the like, and

25 deposited on the surface of the substrate to form a thin film

4

on the substrate. When a reaction gas which reacts with the

cathode material 16 to form a chemical compound is used for

the gas 4, a compound thin film may be formed.

When an electron is transported in a uniform magnetic

5   field, as well known, the electron makes a gyrating movement

such that it winds round the magnetic field lines, under Lorentz

forces given by the following equation 1. In the equation,

q is a charge, v is an electron velocity, and B is a flux density

(The same rule applies correspondingly to the description to

10   follow.).

[Equation 1]

$$F = qvB$$

Accordingly, in a uniform magnetic field, electrons

15   emitted from two positions P and Q shown in Fig. 11 move along

magnetic field lines 26 uniformly distributed, reach the

substrate 6, and are incident on positions near positions P_1

and Q_1 corresponding to the positions P and Q.

Actually, a magnetic field developed by the magnetic coils

20   24 is not uniform and has gradients of a magnetic field without

exception. For drift of charged particles, such as electrons,

in a magnetic field having gradients, reference is made to

"Newest Plasma Production Technique", by Yoshinobu Kawai,

published by IPC corporation on 5 August, 1991, pages 12 to

25   21. As described, the charged particle drifts at a drift

velocity V_D given by the following equation 2. In the equation, μ is magnetic permeability, ∇B is a gradient (vector) of the magnetic field, and Bv is a magnetic field (vector), and other things are the same as mentioned above. ∇ is a nabla or

5   Hamiltonian operator...

[Equation 2]

$$V_D = -\mu \ (\nabla B \ \times \ Bv)/(qB^2)$$

————The gradient of the magnetic field will be discussed by

10   using an apparatus which transports the plasma 18 by use of the deflection magnetic field as shown in Fig. 10 (or Fig. 1 to be described later).

A case where the magnetic coil 24 and the pipe 28 are circular in cross section is shown in Figs. 12 to 18. In Figs.

15   12 to 15, the cathodes 14a and 14b are simply represented by two positions "P" and "Q" (the same thing is correspondingly applied to the illustrations of Figs. 19 to 21 to be described later). In Figs. 16 to 18, the cathodes 14a and 14b are specifically illustrated (the same thing is correspondingly

20   applied to the illustrations of Figs. 22 and 23 to be described later and Figs. 2 to 7).

In this case, the nature of the circular magnetic coils 24 gives the magnetic field in the pipe 28 such a gradient ∇ B as shown in Fig. 14 that, an intensity of the magnetic field

25   is lowest at the center 28a of the pipe inside, and gradually

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increases toward the outside. In a case where a plurality of magnetic coils 24 are disposed while being bent as shown in Fig. 10, for example, the lowest intensity of the magnetic field is located at a position somewhat outwardly shifted from the

5   center 28a, actually.

Accordingly, as shown in Figs. 12 and 13, electrons 32a and 32b emitted from the two positions P and Q drift at a drift velocity V_D in the circumferential direction (Fig. 15) by the gradient ∇B of the magnetic field (Fig. 14), as defined in

10   the equation 2. Therefore, the electrons land on the substrate 6 at positions shifted in the circumferential direction. The same thing is true for the ions, and hence the plasma drifts, while being shifted in the circumferential direction.

In a case of Figs. 16 and 17 where two vacuum arc evaporating

15   sources 12 are vertically spaced from each other and arranged along the z-axis, plasma 18 produced by the cathodes 14a and 14b reaches the substrate 6 while drifting in the circumferential direction. A density distribution of each the plasma produced by the cathodes 14a and 14b is usually depicted in a shape of

20   an outward curve; the density is highest at the center of the plasma in cross section and gradually decreases toward its fringe. Accordingly, peaks 36a and 36b and fringes 38a and 38b of a film thickness distribution (viz., a film forming velocity distribution) appear on the surface of the substrate 6 as shown

25   in a Fig. 18 instance. As shown, those peaks and fringes are

7

located at positions shifted in the circumferential direction from positions 34a and 34b corresponding to the cathodes 14a and 14b.

A case where the magnetic coils 24 and the pipe 28 are rectangular in their cross section is illustrated in Figs. 19 to 23.

A magnetic field within the pipe 28 has such a gradient ∇B as shown in Fig. 20 that an intensity of the magnetic field is lowest at a part 28b slightly closer to the outside than the center 28a and gradually increases toward the outside. The gradient ∇B depends on the nature of the rectangular magnetic coils 24 and the arrangement of the plurality of magnetic coils 24 arranged while being bent as shown in Fig. 10 and the like.

As shown in Figs. 12 and 19, electrons 32a and 32b emitted from two positions P and Q drift at a drift velocity V_D, as defined in the equation 2 (Fig. 21), in a downward and oblique direction, which is the resultant of the downward direction and the lateral direction, by the gradient ∇B of the magnetic field 8 (Fig. 20).

In a case of Figs. 16 and 22 where two vacuum arc evaporating sources 12 are vertically spaced from each other and arranged along the z-axis, plasma 18 produced by the cathodes 14a and 14b reaches the substrate 6 while drifting in the downward and oblique direction. Accordingly, peaks 36a and 36b and fringes 38a and 38b of a film thickness distribution appear on the surface

8

of the substrate 6 as shown in a Fig. 23 instance. As shown, the peaks 36a and 36b and fringes 38a and 38b are located at positions shifted in the downward and oblique direction from positions 34a and 34b corresponding to the cathodes 14a and

5 14b:

Actually, a shift of the peak 36a is different from that of the peak 36b. The lateral and downward shifts of the peak 36b on the lower side (as viewed in the z-axis, the same will apply hereinafter.) are greater than that of the peak 36a on

10 the upper side. This fact was empirically confirmed. The peaks 36a and 36b are shifted in directions in which the distance between them increases. Such an example is illustrated in Fig. 23. Where such shifts occur, film formation little occurs at the central part of the substrate 6. Further, the shifts become

15 larger as a distance of the substrate 6 from the vacuum arc evaporating source 12 increases.

Where the peaks 36a and 36b and the fringes 38a and 38b of the film thickness distribution on the surface of the substrate 6 are shifted by the gradient ∇B of the magnetic

20 field, it is difficult to form a film on the substrate 6 as desired. The shift will deteriorate the uniformity of the thickness distribution on the surface of the substrate 6. When comparing with a case where the magnetic coils 24 and the pipe 28 are circular in cross section, in a case where the where

25 the magnetic coils 24 and the pipe 28 are rectangular in cross

9

section, the peaks 36a and 36b of the thickness distribution are shifted apart away from each other, and the shifts of them become larger as a distance between the substrate 6 ad the vacuum arc evaporating source 12 increases. Accordingly, the

5 uniformity of the-thickness distribution on the surface of the substrate 6 is more deteriorated.

Summary of the Invention

Accordingly, an object of the invention is to provide

10 a vacuum arc vapor deposition apparatus and a vacuum arc vapor deposition method which can prevent degradation of the uniformity of a film thickness distribution on a surface of a substrate, which is caused by the drift of a plasma in a magnetic field developed by a magnetic coil.

15 In order to accomplish the object above, the following means are adopted. According to the present invention, there is provided a vacuum arc vapor deposition apparatus comprising: a film forming chamber containing a substrate and being vacuum discharged; a vacuum arc evaporating source for producing a

20 plasma containing a cathode material by vaporizing a cathode by vacuum arc discharge; a magnetic coil for generating a magnetic field for deflecting or converging the plasma produced by the vacuum arc evaporating source, and guiding the plasma to the vicinity of the substrate within the film forming chamber;

25 a coil power source for feeding a coil current for generating

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the magnetic field to the magnetic coil, the coil power source reversing a flowing direction of the coil current fed to the magnetic coil; and a control unit for controlling the coil power source to reverse the flowing direction of the coil current

5   fed to the magnetic coil.

The plasma is guided (transported) to the vicinity of the substrate by the magnetic field developed by the magnetic coils before and after the flowing direction of the coil current fed to the magnetic coils is reversed. The reason for this

10   is that so long as the magnetic field exists, the plasma is guided by the magnetic field.

When the flowing direction of the current fed to the magnetic coils is reversed, the gradient ∇B of the magnetic field remains unchanged, but the direction of the vector of

15   magnetic field B_v is reversed. As seen also from the equation 2, the drift velocity V_D acting on the plasma to be transported is reversed in its direction.

The phenomenon, already stated, that the peak positions of the thickness distribution on the substrate surface are

20   shifted by the drift of the plasma being under transportation, appears in the inverted state on the substrate surface when the flowing direction of the coil current is reversed. This inversion reduces the non-uniformity of the film thickness distribution, thereby preventing the deterioration of the

25   uniformity of the film thickness distribution on the substrate

11

surface.   The result is that a film may be formed more uniformly over a broader area on the substrate.

Brief Description of the Drawings

5   Fig. 1 is a diagram showing a vacuum arc vapor deposition apparatus according to the present invention;

Fig. 2 shows, in a view in the direction C - C in Fig. 1, an arrangement of cathodes in two vacuum arc evaporating sources in a case where a magnetic coil and a pipe are rectangular

10   in cross section;

Fig. 3 shows, in a view in the direction D - D in Fig. 1, drift directions of electrons in a magnetic field by the magnetic coil in Fig. 1, before the coil current is reversed in its flowing direction, in a case where a magnetic coil and

15   a pipe are rectangular in cross section;

Fig. 4 shows, in a view in the direction D - D in Fig. 1, drift directions of electrons in a magnetic field by the magnetic coil in Fig. 1, after the coil current is reversed in its flowing direction, in a case where a magnetic coil and

20   a pipe are rectangular in cross section;

Fig. 5 is a diagram showing film thickness distributions on a surface of a film formed substrate by the cathodes in Fig. 2 before the coil current is reversed in its flowing direction;

Fig. 6 is a diagram showing film thickness distributions

25   on a surface of a film formed substrate by the cathodes in Fig.

12

2 after the coil current is reversed in its flowing direction;

Fig. 7 is a diagram showing film thickness distributions when the Figs. 5 and 6 distributions are superimposed one on the other;

5 Fig. 8 is a diagram showing a case where two thickness meters are located close to the periphery of the substrate;

Fig. 9 is a diagram showing a case where two ion current probes are located close to the periphery of the substrate;

Fig. 10 is a cross sectional view showing a vacuum arc

10 vapor deposition apparatus in related art;

Fig. 11 is a diagram showing electron motions in a uniform magnetic field;

Fig. 12 is a diagram showing a portion of the magnetic coil of the Figs. 1 and 10 apparatus;

15 Fig. 13 is a diagram showing a cross section of the Fig. 12 structure as viewed in a direction C - C in a case where a magnetic coil and a pipe are circular in cross section;

Fig. 14 is a diagram showing a gradation of a magnetic field in a cross section of the Fig. 12 structure as viewed

20 in a direction D - D in a case where a magnetic coil and a pipe are circular in cross section;

Fig. 15 is a diagram showing drift directions of electrons in a magnetic field developed by the Fig. 14 magnetic coil;

Fig. 16 is a diagram showing a structure of each of the

25 Figs. 1 and 10, which ranges from the cathode to the substrate;

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Fig. 17 shows, in a view in the direction of C - C in Fig. 16, an arrangement of cathodes in a case where a magnetic coil and a pipe are circular in cross section;

Fig. 18 is a diagram showing film thickness distributions on a surface of a film formed substrate, which are caused by the cathodes in Fig. 17;

Fig. 19 is a diagram showing a cross section of the Fig. 12 structure as viewed in a direction C - C in a case where a magnetic coil and a pipe are rectangular in cross section;

Fig. 20 is a diagram showing a gradation of a magnetic field in a cross section of the Fig. 12 structure as viewed in a direction D - D in a case where a magnetic coil and a pipe are rectangular in cross section;

Fig. 21 is a diagram showing drift directions of electrons in a magnetic field developed by the Fig. 20 magnetic coil;

Fig. 22 shows, in a view in the direction of C - C in Fig. 16, an arrangement of cathodes in a case where a magnetic coil and a pipe are rectangular in cross section; and

Fig. 23 is a diagram showing film thickness distributions on a surface of a film formed substrate, which are caused by the cathodes in Fig. 22.

Detailed Description of the Invention

Fig. 1 is a diagram exemplarily showing a vacuum arc vapor deposition apparatus according to the present invention. Fig.

2 shows, in a view in the direction C-C in Fig. 1, an arrangement of cathodes in two vacuum arc evaporating sources in a case where a magnetic coil and pipe are rectangular in cross section. Fig. 2 is the same diagram as Fig. 22 described above. In the figures, like or same portions used in Figs. 10 to 23 are designated by like reference numerals. Description will be given placing emphasis on the differences of the embodiment from the related art apparatus.

The vacuum arc vapor deposition apparatus shown in Fig. 1 comprises a coil power source 40 and a control unit 42. The coil power source 40 is used in place of the related art coil DC power source 30 and reverses the flowing direction of coil current I_c , which flow through a plurality of magnetic coils 24,. The control unit 42 controls the coil power source 40 to reverse the flowing direction of the coil current I_c flowing through each magnetic coil 24.

The coil power source 40 may be a bipolar power source capable of feeding bipolar current or may be a combination of two DC power sources; one feeds a positive current, and the other feeds a negative current.

In the vacuum arc vapor deposition apparatus, two vacuum arc evaporating sources 12 are arranged along the z-axis while being vertically separated from each other.

Each of magnetic coils 24 and the pipe 28 may be circular in cross section as in the case described above. In the cases

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of Figs. 2 to 7, the cross section configuration of them is rectangular.

The plasma 18 produced by the vacuum arc evaporating source 12 is guided (transported) to the vicinity of the substrate 6 in the film forming chamber 2 before and after the coil current I_c flowing through the magnetic coils 24 is reversed in its flowing direction. The reason for this is that so long as the magnetic field exists, the plasma is guided by the magnetic field.

When the coil current I_c flows through each magnetic coil 24 in the clockwise direction as viewed from the vacuum arc evaporating source 12, electrons 32a and 32b emitted from cathodes 14a and 14b of the vacuum arc evaporating sources 12 drift obliquely and downward at a drift velocity V_D as shown in Fig. 3. With the drift of the electrons, the plasma 18, which is produced in the vicinity of the cathodes 14a and 14b and is transported by the magnetic field, drift in the same direction as of the electrons. As a result, peak positions 36a and 36b and fringes 38a and 38b of a film thickness distribution of a thin film formed on the surface of the substrate 6 appear at positions shifted obliquely and downward as shown in Fig. 5. Figs. 3 and 5 respectively correspond to Figs. 21 and 23 mentioned above. The reason why the drift velocity V_D and the thickness distribution are shifted are as already described in detail.

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When the flowing direction of the coil current I_c fed
to magnetic coils 24 is reversed, i.e., in the counterclockwise
direction as shown in Fig. 4, the gradient ∇B of the magnetic
field developed by the magnetic coils 24 remains unchanged,
but the direction of the vector of magnetic field B_V is reversed.
As seen also from the equation 2, the drift velocity V_D acting
on the electrons 32a and 32b is reversed in a direction opposite
to that in the Fig. 3 case. With the drift of the electrons,
the plasma 18, which is produced in the vicinity of the cathodes
14a and 14b and is transported by the magnetic field, drifts
in the same direction as of the electrons drifting at drift
velocity V_D.

As a result, the phenomenon, already stated, that the
peak positions 36a and 36b and the fringes 38a and 38b of the
thickness distribution on the substrate surface are shifted
by the drift of the plasma being under transportation, appears
in the inverted state, viz., by inverting a state of the Figs.
3 and 5 case. Its state is shown in Fig. 6. The peaks 36a and
36b or the like of the film thickness distribution by the cathodes
14a and 14b are shifted obliquely and upward from the positions
34a and 34b corresponding to the cathodes 14a, 14b while a
distance between them increases.

By reversing the flowing direction of the coil current
I_c, the thickness distributions shown in Figs. 5 and 6 are
superimposed one on the other into a film thickness distribution

17

as shown in Fig. 7. Thus, peaks 36a and 36b and the fringes 38a and 38b of the film thickness distribution appear on the surface of the substrate 6 in a dispersing fashion. When a time t_1 that the coil current I_c flows clockwise is selected

5   to be equal to a time t2 that the current flows counter clockwise, peaks whose magnitudes (film thickness) are substantially equal appear at four positions dispersley. With the dispersion of the peak positions, non-uniformity of the thickness distribution on the surface of the substrate 6 is reduced. Thus,

10   deterioration of the uniformity of the film thickness distribution on the surface of the substrate 6 can be prevented by the drift of the plasma 18 in the magnetic field generated by the magnetic coils 24. As a result, a film may be formed uniformly on a broad area on the substrate 6.

15   The substrate 6 and the holder 8 holding it may be rotated about the center of the substrate 6 in, for example, a direction of an arrow "R" (or its reverse direction), as shown in Figs. 1 and 7. By so doing, the non-uniformity of the film thickness distribution is reduced through the rotation of the substrate

20   6, so that the film thickness on the substrate 6 is more uniform.

         The control unit 42 controls the coil power source 40 to reverse the flowing direction of the coil current I_c after a predetermined time elapses. The reversing operation may be performed one time; however, it is preferable to repeat the

25   reversing operation at predetermined time intervals. If so

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doing, the reducing of the non-uniformity of the thickness distribution caused by reversing the coil current I_c is repeated, and hence, the thickness distribution is more uniform.

The time t1 of flowing the coil current I_c in the predetermined direction and the time t_2 of flowing the same in the reverse direction may be selected to be equal with each other. Those times may be selected to be different so as to enhance the uniformity of the film thickness distribution by reducing the non-uniformity of the film thickness distribution in a more sophisticated manner.

It is preferable to repeat the reversing operation of the coil current I_c direction at short time intervals. The reason for this is that it is possible to reduce the concentration of thermal stress on the substrate 6 by ions in the plasma 18 which are incident on the substrate, and hence the thermal stress concentration on the substrate is reduced. One of the preferable ways is to reverse the flowing direction of the coil current I_c at a time interval, which is integer times as long as a time taken for one rotation of the substrate 6. In a specific example, where the time taken for one rotation of the substrate 6 is 5 seconds, the flowing direction of the coil current I_c is reversed at a time interval of 10 seconds.

To more improve the uniformity of the film thickness distribution on the surface of the substrate 6, the following thickness or ion current detecting unit may be employed.

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In the vacuum arc vapor deposition device shown in Fig. 8, a plurality of thickness meters 44 each for measuring a thickness of a film formed by the plasma 18 are disposed in the vicinity of the substrate 6. Specifically, in this instance,

5   two-thickness meters 44 are disposed close to and above and below the substrate 6. The control unit 42 performs the control for reversing the flowing direction of the coil current I_c when a difference between film thickness values as measured by the two thickness meters 44 exceeds a predetermined value.

10   Where the thickness detecting unit is employed, the vacuum arc vapor deposition device performs the control for reversing the flowing direction of the coil current I_c for reducing the non-uniformity of the thickness distribution on the surface of the substrate 6 while monitoring the film thickness on the

15   surface of the film formed substrate 6 at plural positions close to the periphery of the substrate 6. Accordingly, the uniformity of the thickness distribution on the surface of the substrate 6 is more improved.

In the vacuum arc vapor deposition device shown in Fig.

20   9, a plurality of ion current probes 46 are provided in the vicinity of the substrate 6, for measuring ion currents I_I which flows when ions in the plasma 18 are incident thereon. More specifically, in this instance, the two ion current probes 46 are disposed above and below and near the substrate 6.

25   Additionally, two current integrators 50 for integrating ion

currents I_I flowing through the ion current probes 46 are provided.

The ion current probes 46 may be kept at ground potential. To

exactly measure ion currents I_I, it is preferable that a bias

power source 48 is provided, and it is negatively biased, as

5   in the instance. The control unit 42 performs the control for

reversing the flowing direction of the coil current I_c when

a difference between current values integrated by the two current

integrators 50 exceeds a predetermined value.

       The reason why a film is formed on the substrate 6 by

10   guiding the plasma 18 to the vicinity of the substrate 6, is

that ions (ionized cathode material 16) in the plasma 18 are

incident on the substrate 6. A correlation is present between

the amount of the incident ions and the film thickness. The

amount of the incident ions is measured by using the integrated

15   value of the ion currents I_I.

       Accordingly, by using the ion current detecting unit as

mentioned above, the vacuum arc vapor deposition device performs

the control for reversing the flowing direction of the coil

current I_c for reducing the non-uniformity of the amount of

20   the incident ions while monitoring the amount of incident ions

on the substrate 6 at plural locations close to the periphery

of the substrate 6. This further improves the uniformity of

the thickness distribution on the surface of the substrate 6.

       Also in the case where the magnetic coil 24 and the pipe

25   28 are circular in cross section, the plasma 18 drifts by the

gradient ∇B of the magnetic field, thereby impairing the uniformity of the thickness distribution on the surface of the substrate 6, as described with reference to the Figs. 13 to 15, 17, and 18. In this case, however, the direction of the

5 drift of the plasma 18 may be reversed by reversing the flowing direction of the coil current I_c. With this, the non-uniformity of the thickness distribution may be reduced. Specifically, the degradation of the uniformity of the thickness distribution on the surface of the substrate 6 is prevented by the reversed

10 drift of the plasma 18 in the magnetic field developed by the magnetic coil 24.

In the embodiments mentioned above, a deflection magnetic field is developed by the plurality of magnetic coils 24, and the plasma 18 is deflected and transported. If required, the

15 plasma 18 may be guide to the vicinity of the substrate 6 by the magnetic field, while not defected by the magnetic field. In this case, the macro particles are made fine by converging the plasma 18 to increase the density of the plasma by one or a plurality of magnetic coils, as described above. As long

20 as the plasma 18 is transported by using the magnetic field developed by the magnetic coil, the above-mentioned gradient ∇B of the magnetic field exists, and it causes the plasma 18 to drift in the predetermined direction. This deteriorates the uniformity of the thickness distribution on the surface

25 of the substrate 6. Similarly, in this case, the direction

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of the drift of the plasma 18 may be reversed by reversing the flowing direction of the coil current I_c. Accordingly, the non-uniformity of the thickness distribution may be reduced.

The present invention thus constructed has the following
5   useful effects.

The vacuum arc vapor deposition device of the invention includes the coil power source and the control unit. Accordingly, the flowing direction of the coil current fed to the magnetic coils is reversed. As a result, the phenomenon
10 that the peak positions of the thickness distribution on the substrate surface are shifted by the drift of the plasma being under transportation, appears in the inverted state on the substrate surface when the coil current fed to the magnetic coils is reversed in its flowing direction. This reversion
15 reduces the non-uniformity of the film thickness distribution, thereby preventing the deterioration of the uniformity of the film thickness distribution on the substrate surface. The result is that a film may be formed more uniformly over a broader area on the substrate.

20   When a plurality of vacuum arc evaporating sources are provided, and the magnetic coils generate a deflection magnetic field, the non-uniformity of the thickness distribution by the drift of the plasma is easy to occur. In this case, the effect of improving the non-uniformity of the film thickness
25 distribution is more remarkable when the coil power source and

the control unit are provided so that the flowing direction

of the coil current fed to the magnetic coils is reversed.

In the vacuum arc vapor deposition device of the invention,

the reducing operation for the non-uniformity of the thickness

5 distribution by-reversing the flowing direction of the coil

current may be carried out repeatedly. Therefore, the

uniformity of the thickness distribution is improved.

The vacuum arc vapor deposition device of the invention

may perform the control for reversing the flowing direction

10 of the coil current to reduce the non-uniformity of the thickness

distribution while monitoring the film thickness on the surface

of the film formed substrate at a plurality of locations close

to the periphery of the substrate. Accordingly, the uniformity

of the thickness distribution on the surface of the substrate

15 is improved.

The vacuum arc vapor deposition device of the invention

may perform the control for reversing the flowing direction

of the coil current to reduce the non-uniformity of the amount

of the incident ions while monitoring the amount of incident

20 ions on the substrate in a plurality of locations close to the

periphery of the substrate. Accordingly, the uniformity of

the thickness distribution on the surface of the substrate is

improved.

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